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THE EFFECTS OF SAMPLE PLOT SIZE AND SHAPE ON ACCURACY OF INENTORY USING SYSTEMATIC SAMPLING IN *ACAICA NILOTICA* (SUNT) PLANTATION:CASE STUDY SAWLELL FOREST IN BLUE NILE SUDAN

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Dedication

To my Mother
To my father
To soul of my colleague Bashier Abdalla ELabbaS

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ABSTRACT

The present study compares between different sizes and shapes of sample plot in forest inventory depending on systematic sample method in Sawlell forest in the Blue Nile State.

Different sample plot sizes of *Acacia nilotica,* by namely 0.05, 0, 1 , 0.15 hectare with different shapes: circular, square, rectangular were compare to find their effect on forest inventories concerning diameter at breast height, basal area, height, number of trees, and volume estimates the complete enumeration was taken as control.

The selected study area was Sawlell forest in Blue Nile State. The forest age is approximately 21 years the research was done in Maya site. The karab site is not re preventative area and for graf site is covers by the plantation of *khaya senegalensis* , *Eucaly ptus* and *Tectona grandis*.

The study showed significant difference between the different sizes and shapes of the sample plots .The study clearly indicates that the most accurate results of diameter, height, basal area, number of trees and volume estimates were achieved by circular sample plots compared to square and rectangular sample plots.

The present study indicated that the total number of trees obtained by 0.1 hectare systematic sampling is close to the total number of trees for the compartment given by the total enumeration. Also the results indicated that the diameter distribution using 4.0 cm class range is similar to the distribution provided by the complete enumeration.

ملخص الأطروحة

أجريت هذه الدراسة فى غابات السنط بولاية النيل الأزرق(غابة ساو ليل) للمقارنة بين أحجام و أشكال العينات بالأعتماد على الطريقةالمنتظمة حيث أخذت عينات بأحجام 0.05 هكتار، 0.1 هكتار، 0.15 هكتاربأ شكال مختلفة،دائرية ومربعة و مستطيلة للمقارنة بينها و تأثيرها على مساحة قطعة العينة فى الحصر الغابىفيما يتعلق بالقطر والمساحه القاعديه والإرتفاع و عدد الأشجار وتقدير الحجوم وذلك لمعرفة تأثير أحجام وأشكال العينات على الدقة للمقارنة بالحصر الكامل. تم أخذ عينات من أشجار السنط من غابة ساو ليل بولاية النيل الأزرق وعمرها حوالى 21 سنة وتم التركيز على موقع الميعة فى الغابة لأنها مناسبه للبحث نسبة لأن الكرب فقير بالأشجار و الجرف ملئ بزراعات المهوقنى و البان والتيك . فى هذه الدراسه تمت المقارنه بين مساحة وشكل العينات باستعمال الطريقة العشوائية المنتظمة. أثبتت الدراسه وجود فرق معنوى بين الاشكال والمساحات المختلفه للعينات واظهرت الدراسه بأن العينات ذات الأشكال الدائرية لكل مقاييس المساحة تعطى دقة أكثرفى القطروالارتفاع والمساحه القاعديه وعدد الاشجار وتقديرالحجوم مقارنة الأشكال المربعة و المستطيلة بالمقايس المختلفة للمساحات المأخوذة فى الدراسة. كماان هذه الدراسه اعطت مؤشرات ان عدد الاشجار فى حجم العينه 0.1 هيكتار بالطريقه المنتظمه يعطى تقدير لعدد الاشجار لا يختاف معنويا عن التقدير بواسطه القياس الكلى . كذلك مؤشرات النتائج اوضحت ان توزيع القطر باستعمال 4.0 سم كمدى صفوف يعطىدرجة من الدقةأفضل من استعمال الصفوف 2.0 سم او 3.0 سم .

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Chapter I

Introduction

1-1 General

The Sudan is the largest country in Africa with an area approximately 2.5 million square kilometers, about 250.0 million hectare is extending in the dry region of Africa between latitudes 3° and 23°N and longitudes 22° and 38°E (Figure 1.1). It is characterized by a diversity of climatic conditions. The Arid zone constitutes the Northern half of the country with average annual rainfall from 0-30 mm. the southern half comprising the savannah region that is divided into two divisions. Low rainfall woodland savannah and high rainfall woodland savannah, (Harrison and Jackson 1958).

The area occupied by forest is approximately 30%of the total area of Blue Nile State .The riverian forests constitute special sites. Where Most of the area is occupied by *Acacia nilotica* (Sudan Energy hand book 1997 F.A.O 1993). The productivity of Blue Nile State forests is very high as result of the management plans (Elisddig 2002).

1.2 Botanical distribution

Acacia nilotica (l) wild Del is called sunt and also named Garad which refers to the pod. It is an extremely variable species in its morphological characters (ELAmin .1980; Elsheikh 1981).

1-3 The importance of *Acacia nilotica*

Acacia nilotica trees timber products are widely used for railway sleepers, fuel wood, building, houses, doors and windows, native beds, steads, furniture building boats. The Pods are used for tanning and Medicine and the leaves are used for fooder by domestic animals (Elsheikh1981; Suleiman1987).

The *Acacia nilotica* forest annually produces about 4,90 thousand M^3 sawn timber, 80,060 thousand M^3 of firewood and a large number of round poles. In addition to the economic role of *Acacia nilotica* forests they have also an important role for soil conservation as well as they give indirect benefits to the
local people.

Forest products consumption survey in Sudan (F.N.C 1994) indicated that demand for saw logs and poles for construction, and logs for furniture during 1994 made a total of 1.966 million M^3 (Table.1). This demand will rise continuously with rise in population improvement in standard living. The main objective for A. nilotica production of railway sleeper and fuel wood, building boles and the maintenance of the Nile eco-systems.

Table (1.1): Wood consumption (M^3) in Sudan

Sector	Poles and saw logs			Total
	construction	maintenance	furniture	
Houses hold	113172	573002	201768	887842
Industrial	1796	689	1359	3844
Commercial services	17862	21594	34837	74293
Quranic schools	393	000	0000	393
Total	1133223	595285	237964	1.966
Percentage	7.2%	3.8%	1.5%	12.5%

Source: Forest product consumption survey May 1995.

Forty-four forest reserves extend along the Blue Nile South Sennar with a total area of approximately 21 thousand Feddans. Thirty-seven reserves North of Sennar with a total area of approximately 14 thousand Feddans and twelve reserves along the White Nile with an area of 93,020 Feddan (working plan for Blue Nile 199 7). Illegal felling by man activities is the main reason for the decrease of forestland in sector due to encroachment by the local farmers for private gardens (Table 2).

Table (1.2): Decrease of forestland in Blue Nile

State	Total forest area (faddans)	Encroachment (faddans)	Encroachment area % of total
Gezira	12346,153	819.920	6.64%
sennar	15877.430	1359,430	8.6%
Blue Nile	7122,000	214,370	3%
G/ total	35345,583	2393,720	(average 6.77)

Source: Working Plan Blue Nile.

Sunt plantations are managed under working plans that aim at producing saw logs **mainly for the producing railway sleepers. These plantations supply two sawmills Al Suki and Wadel Nayal, (Dafa Alla 1998) EL Siddig 1985 stated that the contribution of this species to the total production of sawn timber and fuel wood in the Northern Sudan is estimated to be 40% and 50% respectively. The trend in management of sunt plantation has been toward quantity production rather than quality. However management and silvicultural practice are important factors that effect the quality of trees and logs which in turn affect the utilization of wood in the round and sawn forms, .Much attention has been focused on measuring the volumes of trees and logs (Khan 1964; Ahmed 1976 ; ELSiddig and Hetherington1985;Goda 1987)**

1-4 Project justification

Acacia nilotica (sunt) is economically a very important tree species in the Sudan, especially in the east central region of the country. It is used for a wide variety of local and commercial purposes. Its wood is very hard, utilized for multiple uses.

Apart from these economic and social uses, the tree is also utilized for conservational purposes to help in environmental protection of the Nile ecosystem. The selection of the area in the Blue Nile State is based on the conditions, of the sunt forests that require a suitable inventory design.

The *Acacia nilotica* forests are providing, multiple uses in the country and produce large quantities of forest products including timber and non-timber products. Sawmilling industry in the Sudan started in 1935 based on wood produced annually from sunt. Mukhtar (1979) mentioned that the forests service of the Sudan has formulated many practices for development of wood-based industries in the Blue Nile State.

However studies are needed for developing inventory procedure based on efficient shape and size of sample plots with acceptable accuracy using systematic sampling.

Sunt plantations are managed for productions of wood and other uses on a sustainable management basis. This requires high precision of growing stock and final harvesting estimates of the resources.

The present study is an attempt to find out the most suitable sample plot size and shape that provide acceptable estimates of stock density to help in planning activities such as thinning, in addition to the estimates of final felling.

1-5 Research problem

To investigate accuracy in estimates of number of trees and volume estimated in relation to the different sampling procedures based on sample plot size and shape in *Acacia nilotica* in the Blue Nile State.

1-6 Objectives of the study

1. To find out the most accurate sampling design using plot size and shape using circular, rectangular and square.
2. To investigate the effect of sample plot size and shape on diameter distribution compared with 100% enumeration.

Chapter 2

Literature Review

2-1 Forest Management

Increasing population and diversification of their needs for forest products necessitates adoption of proper management control and wise use of the forest resources to avoid diminishing of forests and their direct and indirect production (UNDP 1995). Forestry development plans in the Sudan put great emphasis on the establishment of plantations of indigenous and exotic species inside the forest reserves. Various species within the Savanah region have been declared reserved; of these species; *Acacia niltoica* has been found the most valuable timber production species. (Elsiddig and Hetherington 1985). Sunt plantations of the Blue Nile flood basins in the northern fung form a significant resource, whose area extends over 14,000 feddans (6,600 hectares) and new plantations continuing to be established in southern Fung may exceed 5,000 feddans in the future (Elsiddig 1985).

Although the Sudan has had forest legislations policies and forest laws for a long time, forest management is not well established .The main objectives of the forest legislation aim at bringing the forest reserves under sustainable management by the end of 1980´s. But only limited areas have been put under management planning namely the *Acacia nioltica* reiverian forest reserves (approximately 20000 ha). *Acacia nilotica* plantations were sustainable over the first 30 years rotation (1935-1965) with regular area –age distribution. However the sustainability was disturbed over the second 30 years rotation (1965-1995) due to deviation from following the plan prescription. Investigation is going on to accommodate the local communities in the plan prescription and execution as one of the approaches to reduce such disturbance.

2-2 Clear Felling

The final harvesting of *Acacia nilotica* follows clear felling system. This system has a long history in the world and it is adopted with the objective of changing the crop composition in favour of commercially and industrially more valuable species (Husch *et al* 1972). There is however a growing awareness about the possible adverse soil and environmental effect of clear felling (Osmaston 1968). Clear felling exposes the soil to erosion hazard and results in nutrients loss and (saulei, and lamb 1991). In Brazil Russell (1983) found that clear felling removed 47% of the calcium 26% of the magnesium, 71% of the potassium and almost 50% of the nitrogen of the ecosystem.

Restocking of felled areas is accomplished either naturally or artificially. Plantation establishment is required in controlled stocking in pure stands (F.A.O 1989). Both methods of regeneration are followed and choice is determined by a number of factors (Lampricht 1989). Adoption of clear felling system for the management of *A.Nilotica* stands may have some other advantages particularly the successful natural regeneration under clear felling. In the Blue Nile State the plantation of Sunt is established after clear felling by the Taungia system type of agro forestry. Under clear felling system it is too difficult to establish most areas by artificial regeneration.

2. 3. Forest Inventory

A forest inventory is the procedure for obtaining information on the quantity and quality of the forest resource and many of the characteristics of land area on which the trees are growing. Most forest inventories have been used for timber estimates. However the need for information concerning recreation water, wild life and non-wood values has stimulated the development of integrated or multi resource inventories (McClure *et al* 1979). The emphases placed on specific elements for measurement will differ with the purpose of the inventory Husch 1971). For example if the purpose of an inventory is for the preparation of a harvesting plan, major emphasis should be put on a description of topography, determination of accessibility and transportation facilities and estimation of timber quantity. The other elements would be given little emphasis or would be eliminated. But if the purpose of an inventory is for preparation of management plan, major emphasis would be put on estimation of timber quantity and growth (Elsiddig 1980).

Measuring and assessing the trees and various characteristics of the land provide Forest inventory information. The information may be obtained from measurements taken on the ground. When the measurement is taken for the entire forest, the inventory is defined as complete (100 percent} inventory.

The terms cruise in Northern America and enumeration in English speaking areas are frequently used instead of inventory (Chapman, 1978; Meyer 1978; in Mohamed 1997). Forest resources were assessed directly using systematic multipurpose inventory that included minor forest products in addition to timber and watershed management. For assessing and monitoring the relationship between natural resources and their uses, multiple purpose forest inventory were used (IUFRO August 1995).

2.3.1 Quantity Relationship in Forest Inventory

In executing a forest inventory it is impossible to measure directly quantities such as volume or weight of standing trees. Consequently, relationships are established between directly measurable trees or stand characteristics (e.g. dbh, height) and desired quantity like volume and weight (Elsiddig 1980).

2.3.2 Inventory Planning

An important step in designing a forest inventory is the development of a comprehensive plan .Such a plan ensures that all facts of the inventory including the data collected, financial and logistical support and compilation procedures are considered (Husch *et al* 1972) :

1. Purpose of the inventory
2. Background.
3. Description of the area.
4. Information required in the final report.
5. Inventory design.
6. Procedures for fieldwork.
7. Compilation and calculation procedures
8. Final report.

2.3.3 Inventory Design

There must be wide attributes in designing an inventory to meet the variety of forest topographic, and transportation conditions. The funds available and the cost of an inventory will strongly influence the design chosen (Freeze 1964). The main factors that will affect costs are the types of information required, standard of precision chosen, the total size of the area to be surveyed and the shape and size of the sampling unit (Spurr 1952; Loetsch *et al* 1972).

A forest inventory is concerned with species, quantity of forest products and fund within a specified forest area (Idris 1998). It can also be designed to provide estimates of non wood products and land values related to the inventory area.

Three types of forest inventories are identified:

1- Reconnaissance inventory

2. Management inventory

3- Operational inventory

Lund and Thomson (1989) stated that land managers need to know the location, extent, quantity and condition of forest resources they manage and how those resources are changing over time .For these purposes detailed inventory is needed. Such inventory falls in the type identified as management inventory.

Husch *et al* (1972) explained that most forest inventories in the past have continued to be timber estimates. Need developed for inventories that collect information of multiple purposes.

In this sense a forest inventory is an attempt to describe the quantity and quality of forest, trees and the many characteristics of the land areas upon which the trees are growing with increasing importance of forests for non–wood values such as recreation, watershed management, wildlife or possible conservation to other land. Timber and non-timber characteristics of the forest and the land, upon which it is situated, will have to be measured where possible and the resulting data analyzed (Ffolliott, p.and Worey.d.p1965).

“Wensal and John (1969) stated that a forest inventory is concerned with the quantities description of forest community as a basis for some management decision. In some cases a forest inventory will seek only wood and timber quantities and qualities in other cases both timber and non- timber information may be sought (Booth and Richans 1988). Inventories include local, regional or national assessments of forest resources .Inventories can be based on management of forest cover or compartment to provide detailed data for intensive and appropriate management options. Regional and national assessments are used to determine area condition and volume for specific purposes such as developing resource management policies and programs (Cunia 1974). Such surveys usually consist of widely spaced systematically located fixed size or variable size plot sampling units (Loatesch *et al* 1972). The plots may be permantly located to monitor trends and changes. The inventory may cover several ownerships (Husch *et al* 1972). To obtain information from forest inventory, it is necessary to make a number of measurements on the trees which form the forest and additional observations including land survey (Brickell 1992). These measurements can to take for the entire area of forest and all measurement on the trees. In this case it is called a complete or 100 percent tally inventory. When the measurements are taken on sample portions of the forest it is called sampling inventory (Husch *et al* 1972). Few inventories use 100% enumeration and most inventories rely on sample drawn from population (Wenger 1984). The forest inventory design is an art in which the knowledge and experience of the inventory specialist is combined to prepare a methodology which will yield the required information (Monab 1997, Laux 1984). Forest inventory consists of at least three phases

- Mapping
- Sampling
- Analysis

The steps of forest inventory taken for inventory design include:

- Objective of the inventory.
- Background, concerning area and resource description
- Outputs with standards of results and precision
- Inventory design including sample units, size selection and in addition should cover staffing and manpower
- Funding-time frame requirements and compilation procedure.

The consideration of these steps results in effective and efficient inventory (Husch *et al* 1972).

Inventory planning is necessary to be considered at early stages, in order to consider the kind and the final information by those using the results (Husch *et al* 1972). This is a prerequisite of efficient inventory planning that contributes in time and money savings (Elsiddig 1992). Decisions on the kind of required information influence subsequent inventories and render them, efficient if all aspects are covered.

In the planning of a forest inventory for timber volume estimates a decision must be taken concerning which of the several alternatives will be used for covering directly measurable tree dimensions to facilitate volume estimates. The alternatives include the use of volume equations, form factor or mean tree

tariff systems (O.Flanagam 1972). In all the phases of inventory planning a comparison of the time and costs involved in using the several alternatives must be taken into the decision process.

2.3.4 Errors in forest inventory

Husch *et al* (1972) stated that all forest inventories are subject to errors, which can be grouped into two classes: sampling errors and non-sampling taken together make up the total error of the estimate. The total error is the difference between the estimate taken from a sample and the true population value (Freeze1964). If no non-sampling errors are present the total error is equivalent to the sampling error (Freeze1964). The precision of a forest inventory is based on sampling and is indicated by the size of sampling error and excludes the effect of biases (Husch *et al* 1972).

In any sampling procedure in forest inventory more concern is directed to the accuracy on the estimate (Saxin Willgenstein 1965). Accuracy is achieved by designing an inventory for the maximum precision and by eliminating or reducing bias to a minimum (Husch et al 1972). In forest survey it is general practice to select a sample consisting of a small fraction from a forest. The true value of a characteristic of a population is called a parameter and the estimated value of a characteristic based on the observations from the sample is called a statistic (Zar 1972). The statistic is an estimator of the corresponding parameter. For instance the true timber volume of a forest is a parameter, which exists in nature but would be very costy to measure. By investigating a certain number of sample plot properly selected from the forest an estimate of the timber volume for the whole forest can be made. Such an estimate of a statistic or estimate of parameter is naturally subject to the error of sampling.

2.4 Sampling

The size of sample plot usually varies directly with the size of trees and in the stand under investigation. The number of plots often has inverse relation to the size of the sample plot, owing principally to the ease of measuring small plots as compared with measuring large plots. (Chapman and Meyer 1949).

2.4.1 Size and shape sampling unit

The size of the most efficient sampling unit depends on the variability and density of the stand and the cost. The sample plot size has some effect on the number of sample plots, the number of plots will be few when the plot size is large, thus will involve less travel time in locating the plots. But the relative time of actual enumeration of the plot will be more compared to the small size plots. The over-all time and cost are considered for the complete task (spur 1952).

Plot shapes such as circular, square rectangular and diamond like are used in different countries for surveys. The inventory in Finland is based on circular plots of 1000 sq meters in size and regularly spaced at 500 or 1000 meters .intervals on lines 6.5-20 km apart. In Sweden in the second national survey the most acceptable type proved to be circular plots with an area of 138 sq meters.

The Temu (1990) stated that a statistical design of a forest inventory should be a relatively easy task if the population parameters and their estimates can be clearly and unambiguously defined. The sampling design to meet inventory objectives is determined by the kind of sampling units, their size, shape, the number to be employed, the manner of selection and resultant distribution over the forest area (Spurr 1952, Loetsch *et al* 1972, Stage 1992) .Systematic sampling, random sampling, strip sampling, cluster sampling, two stage sampling and sampling on successive occasions are common methods of distribution in forest sampling (Johnson and Hixson 1952, Shiue 1960).However, Complete enumeration results in measurement of all the trees in the compartments of the forest.

The advantage of the complete enumeration is determined by the population mean rather than estimating .However the disadvantage is that the cost is very high, (Husch *et al* 1972) . Sampling on the other hand is the most basic technique in choosing a representation for the population (Freeze 1964, Shiue 1960). When the sample units are selected at equally spaced intervals over population it is a systematic sampling (Suchatme1954; Gautschi 1957).

Most plots shape are circular, square, rectangular or triangular but circular plots are most commonly used (Loetsch *et al* 1972). The size of plot should vary with the type of timber being sampled. In USA plot sizes a very between 0.05-0.25 ha depending on tree size and density (Wenger 1984). Johnson and Hixon (1952) compared between inventories using different size and shape of plots to conclude the most efficient type. The units of population may be of different size. The size of sample is the sum of the size of the sampling units. The sampling intensity is equal to the ratio of the sample to the total size of

population. If the population has units of equal size and if the sample has been made up by selection of (n) different sampling units then the sampling intensity or sampling fraction:

$$F = \frac{n}{N}$$

2.4.2 Sampling in forest inventory

The design of a statistical sampling scheme include decisions on the following questions

(i) The type and the size of the basic sampling units

(ii) Number of sampling units in other words of intensity of sampling.

(iii) The distribution of analysis of the data

The sampling technique to be used in forest inventory varies not only with the purpose of the study but with kind of timber and forest produce and the geography as well. For over- all planning and development of forestry in general the survey results may be required only according to forestry administrative units involving fairly extensive areas. For intensive management and exploitation of valuable species information is needed for small tracts. The intensity of enumeration and techniques recommended may differ accordingly (spurr 1952).

A sampling scheme is determined by the type and size of the basic sampling units, number of sampling units to be used, the distribution of sampling units over the entire area to be sampled, the type and method of measurement units and the statistical methods for analyzing the data for estimating the population values. The selection of a sampling design depended not only the accuracy of the estimated but also on the cost of sampling in forest inventory (Loetsch *et al* .1972).

2.6 Diameter distribution

There is generally a relationship between species temperament and the stem diameter class distribution. The shade tolerant species have an all-age population structure, which gives the characteristic inverse J-shaped curve a negative exponential stems distribution (Rollet- 1974, Veblen et al 1980, Geldenhuys 1992, Sokpon 1995). Such species have expanding or stable population in the particular situation (Geldenhuys, 1992). The bell shaped distribution species are generally considered as light demanding species. They are gap- depending for their regeneration species. Mortality is higher in earlier stages under closed forest canopy.

More caution is required as far as species temperament and stem diameter and stem diameter class distribution are concerned. The stem diameter of species greatly varies with observed plot size. Some species having a bell shaped distribution within small plot could show inverse J-shaped when plots are larger (Koubouana, 1993). In Ghana for instance (Howthorne, 1995) showed that on a national level the majority of species have sufficient natural regeneration and most species show inverse J-shaped curve. So population structures were not very consistant.

Chapter 3

Study Area

3-1 Location

Blue Nile State is located in the southeastern part of the Sudan between latitudes 35◦ 80' E 33◦ 8'E and longitudes 12◦ 35'N-9◦ 30' N. It is the first state to be crossed by the Blue Nile River through its great Journey where it meets with the White Nile in Khartoum junction Mogran. The total area of the state is 38,500 km square, adjacent the to Ethiopia from the east and the south Sennar State from the north and the east and upper Nile State from the west.

3.2 Administration structure

Referring to the Constitutional Act number (4) of the year 1993 Republic of the Sudan was divided into 26 states in the established states the Blue Nile State is one of them. The state of Blue Nile consists of into 4 provinces these are namely: Damazin, Rosaries, Kurmuk and Bau. The province consists of into several localities for administrative purposes (Blue Nile, plan 1995)

3.3 Climate

The southern part of the state that lines between lat. 9º N and land goes two aids the northern eastern direction to in clued Khore Yabous in lat 11º N and Geesan area, the rain fall ranges between 900-1000mm in most clime. The second part of state the ranges rainfall 700-900mm and lines between 9◦N-12◦N. The third part the annual rain fall between 450-700mm. The remaining part of this state is within the semi-arid climate with an annual between 200-450m.

The minimum average temperature is between 17-21in July, the maximum average temperature is 31◦-32◦ in April. The rainy season starts in April an and ends of him in November each year, every season the most effective rain for agriculture starts in June (Blue Nile Plan 1995).

3.5 vegetation

The high rain savanna belt covers the lines of State. For this reason there is a wide diversity of vegetation that includes the distribution of tree cover vegetation depending mainly on the quantity of the annual rainfall and the soil types (Harrison and Jackson 1958). The soil of the Blue Nile State is a heavy clay soil with an average annual rain-fall ranging between 500-1000 mm . The tree cover vegetation is divided into three categories according to the distribution of the types of soil and rainfall.

3.5.1 The river forest

Approximately 30% of total area of the Blue Nile State is occupied by forests of which 2% are reverian forest. These forests are classified into three topographical categories.

- Maya, depression which is occupied by Acacia Nitolica (sunt).
- Karab which is occupied by the *Balanites aegytiaca* (Higleeg) *Acacia nubica* (laout), *Borruss aethoipium* (Dalaib), *Acacia seberiana* (koke) *Tamarandus indica* (Aradiab) ,*Acacia mellifera* (Kitir)
- Gerf occupied by Eucalyptus spp (kafur), Khaya *senegalensis* (Mahogany)*Oxytenanthera abyssinca*,(Gana) *Maerua crassifoolia* (Andrap) .

3.5.2 The Savanna belt with law rainfall

The average rainfall between 300 mm-500mm) is occupied by kitir (*Acacia mellifera)* belt in North on part of the state. The natural regeneration rate is affected by different hazards like, fires that occur annually and illegal cutting.

The second belt is Higleeg and Talih belt with average rainfall between 570-800 mm.The tree species in this belt include *Acacia seyal var seyal* (Talih) *Acacia seyal var Fistula* (soffar), *Balanites aegptiyca* (Higleeg) *Acacia polycantha* (Kakmout) *Dalberiga melanoxlon* (Abanous) and *Acacia senegal* (Hashab) (Abdullah,2002).

On the clay plains with heavy density the seeds of those species are usually washed by rainwater and substituted by tall gross (of sorghum species) this was known as Acacia-grass rotation.

The third belt is Sahab (*Anogeisus leiocarpus*) and Habil (*Combretum cordofanum*) belt where the average rain fall is more than 800mm the most important tree species are sahab, layoun(*Lannea schimperi),* khashkhash (*Steseparmer Kanthianum),* Subag(*Terminalia laxiflora*), Abanous*(Dalbergia melonoxylon*) and saraya (*Maesa Ianceolata*). This belt extended up to the southern part of the state and ingassana hills.

3.5.3 The riverian series

This extended all the away riverian mountings from the Ethiopian mountains up to ingassana Hills.

The dominant species is *Boswellia paprifera* (Tarag tarag) *sterculia setigera* (Tartar) *combretum* Sculeatum Habil, *Steseparmer Kanthianum* (Khashkhash). *Adonsonia digitata* (Tabaldi) Oxytenanthera abyssinica (Gana*) Anogeissus leiocarpus* (Sahab) *Diospulos mesipifrorom* . Vegetation distribution comes is result of topography ,of soils and quantity and distribution of rain fall the diversity of hill soils.

3.6 Soils

According to the FAO analysis department classifies the Blue Nile soils to geographical sites to the following types from north to south: loamy soils, clay soils, silt soils and heavy clay soils (Blue Nile Plan 1995). Following from south to north the Bule Nile State traverses the vast clay plain. The soil of these plains is referred to as cracking clays a term that describes the cracking nature of the soil during the hot dry weather. The soil of the flood basins of the Bule Nile exhibit some variations from that of the clay plains. Here the soil may be classified into three major soil groups related to the topographic classes. The dominant soil of the Maya is typical of the dark, cracking clays believed to have been brought from the clay plains by water run-off .It is a black , clay soil that cracks widely in the dry season. The Karab slops are eroded slops characterized by a higher contain of sand and gravel exposed as a result of erosion. The Gerf slops on other hand have deep permeable silt deposits known to be the most fertile type of soils. The clay plain soils and the flood basins soils have been influenced mainly by weather factors (Elsiddig and Hetherington, 1985).

3.7 Sawlell Forest

Sawlell forest is one of Riverian forest in the Bule Nile State. The total is 3133, 6 faddan .The forest is classified into three topographical categories.

- Maya: 421.68feddan
- Karab: 2593.618 feddan
- Gerf: 70.5 feddan

The main purpose of this forest is to supply wood timber to Sawlell Sawmilling .The first clear felling in 1995 and replanted in 1998.the establishment of fire line in 1990.The forest was exposed to over grazing .The average number of trees per feddan was 8-12 . The average dbh was 36.0 cm, the average height was 13.0 cm (FNC office Blue Nile State)

Table (3.1). Sawlell forest information.

Compartment number	Age	Average dbh	Average ht	Date of plantation	Date of felling	Area per faddan
1	2	36	13	2002	95-2002	58,80
2	3	36	13	2003	95-2002	70.2
3	21	36	13	1983	-	108,3
4	21	36	13	1983	-	87,2
5	21	36	13	1983	-	98,53
6	21	36	13	1983	-	78

Chapter 4
Research Methodology

4.1 General

In the present study basic information of site type characteristics concerning A*cacia.nilotica (*sunt) in the Blue Nile State was collected from Blue Nile State forest offices. The information included forest conditions in all forest districts as well as areas, forest maps, ages, previous inventory data, silvicultural operations, production, protection and literature. The information collected was used as the basis for planning the study design and basic data concerning management options.

Field visits were made covering *Acacia nilotica* plantations on different sites of the Blue Nile State to select a suitable area that can be considered as the most representative of *A. nilotica* plantations of the Blue Nile State. Sawlell forest was selected as the most suitable site for the field research. Compartment 3, 4 and 5 were selected to represent the sunt of sawlell as being of approximate by equal age.

4.2 Survey and Mapping

In the present study the area of the sunt compartments was 50.0 hectares. The area was inventoried in a two-stage procedure. The first stage involved complete enumeration .The second stage was composed of sampling procedure in which three sample plot shapes were used and for each shape three sample plot sizes were used

The three-sample plot shapes included:

Circular

Rectangular

Square

The three sample plot sizes were

0.05 hectare

0.1 hectare

0.15 hectare

4.3 Inventory equipment

The equipment used for the inventory included:

50-meter distance tape

A compass

Ranging rods

Diameter tapes

Height hypsometers

4.4 The inventory

4.4.1 Complete enumeration

Complete enumeration was based on survey strips in order to control the measurements and record of each single tree in the strip. The compete enumeration involved measurement of the dbh of every tree and all trees in the strip were recorded in separate sheets under complete enumeration.

4.4.2 Sample plots

The procedure for location and measurements of each sample plot size was carried out separately but for each size the three sample plot shapes were executed together at the same location. Each sample plot size and the three shapes represent a sampling group. The circular sample plot center was first located and the circular plot demarcated and measured. The design of sampling for each group is shown in table (4.1) the center for the circular plot was used as the center of the rectangular and hence the center of the square.

Table (4.1) sample plot size and sampling percent

Sample plot size (ha)	Sample plot area sq.m	***Circular radius***	ctangle sides	quare sides (m)
0.05	500	12.62	20*25	22.3
0.1	1000	17.85	20*50	31.6
0.15	1500	21.86	30*50	38.73

The sampling procedure for the three sample plot sizes (0.05 hectare 0.15 hectare and 0.1 hectares) was the systematic line plot sampling . The distance between the lines was 80 meters and the distance between the sample plots was 50 meters. Starting with the 0.1 hectare plot size, the first survey line was established at 50 m from the northern boundary line of the inventory area. Then the first plot was established on the survey line at 50m from the southern boundary line. The first center was located at the end point of the first 50-meters. The circular plot of 0.1 hectare was located by using a radius of 17.81 meter and marking all the trees outside the circle.

The diameter at breast height “DBH” for every tree inside the circular plot was measured in cm using caliper

Then a random sample of trees was selected for height measurement by dividing the dbh range into two groups selecting one tree from each group for height. Using the center of the circle, the rectangular and square plots were demarked separately. As in the case of the circle, all trees for the rectangle and square were measured for dbh. Also two height trees were measured following the same procedure as in the circular plot.

The sampling procedure was repeated for the 0.15 hectare and 0.05 hectare following the same procedure as in the case of the 0.1-hectare. For each sample plot size for each shape the data was recorded in separate sheets.

4.5 Analysis

The results of 100% enumeration were used as true value to provide the basis for comparison between the different sampling by the size and shape. The values obtained from sample plots were used to test the hypothesis that the mean of the sample is not significantly different from that of the population obtained using100% enumeration, equation 4.1 was used for this purpose

$$Z = \frac{\bar{X} - M}{S\sqrt{n}} \qquad \text{....................} \; 4.1$$

Where:-

$\bar{X}$ = the mean obtained by a given sampling procedure

M = the mean of the population obtained by 100% enumeration

S = the sample standard deviation

n = number of sample plots

Z= the difference between the sample mean and the population mean

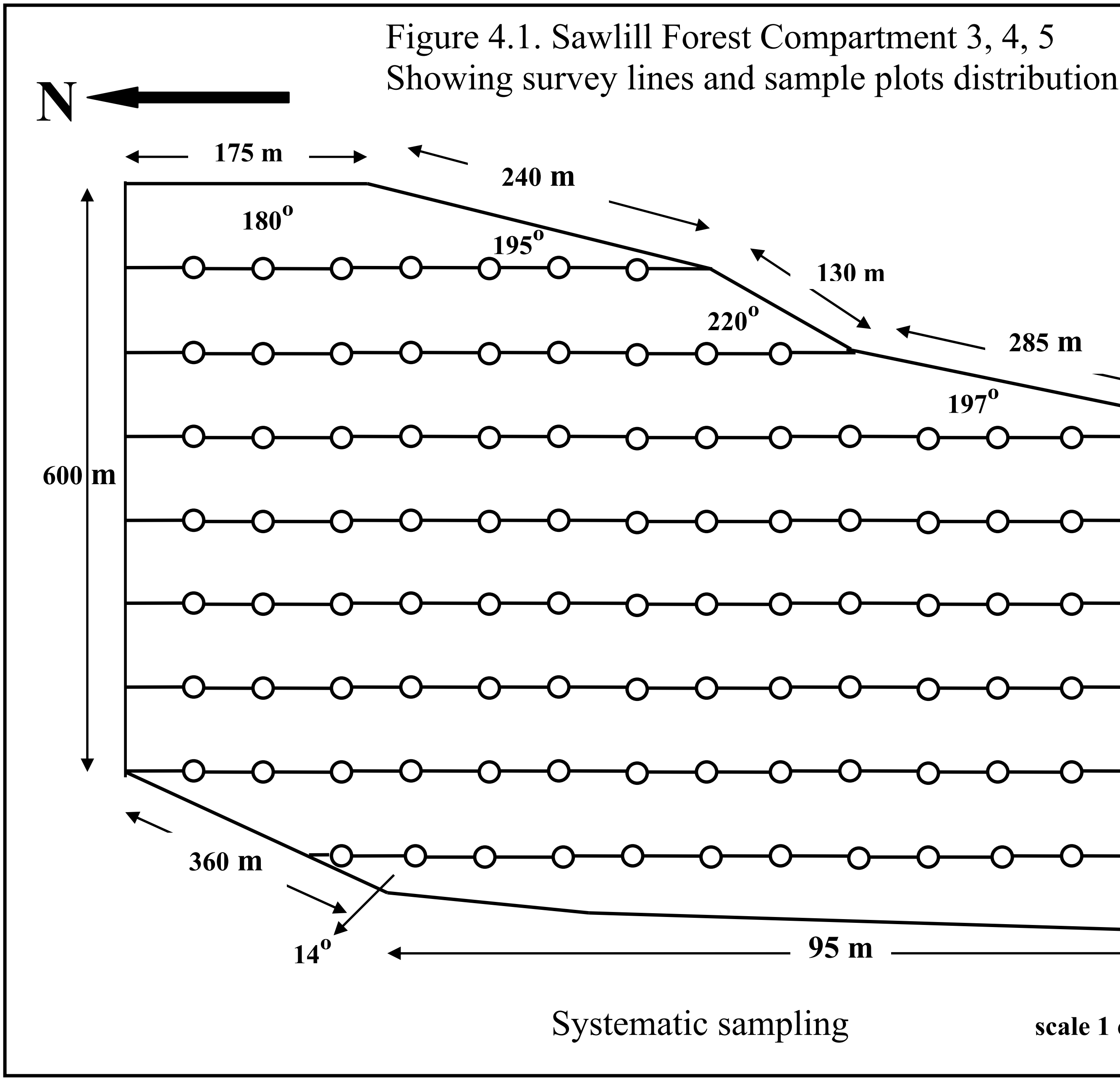


Figure 4.1. Sawlill Forest Compartment 3, 4, 5
Showing survey lines and sample plots distribution
N
175 m
240 m
130 m
285 m
180°
195°
220°
197°
600 m
360 m
14°
95 m
Systematic sampling
scale 1

5.1 General

Chapter 5

Results and Discussion

5.1 General

The Sudan national forest policy states that the Sudan develops hard wood plantations in order to attain self- sufficiency with respect to hard wood supply. The major goal involved establishment of hard wood plantations at the Blue Nile. Reporting on working Plans for *Acacia nilotica* at the Blue Nile indicated that the plantations achieved sustainable production of sawn timber and firewood. Most of the Sunt plantations in the Blue Nile are based on sunt as an indigenous tree.

The establishment and management of the plantations were planned to satisfy the clear felling management system requirements decided upon to be adopted as a mechanism for yield regulation to attain sustainable production system both in kind of produce as sawn timber and firewood .The system regulated on area / age basis organized into single compartments.

Inventories were previously based on strip sampling measurement of all. At a later stage sample plots of 0.1 hectare have been used for the inventory of compartments. The present study attempts to analyze the application of sample plots procedure for compartment inventory. Three classes of size and three shapes were used in systematic sampling to give the means of comparison for accuracy obtained in relation to the different sampling procedures on *A.nilotica* in the Blue Nile. The results are expected to provide required precision of diameter, basal area and volume estimates to facilitate accurate statistics of forest products to have confidence in the supply of the forest products.

5.2 sample plots size and shape

The statistical tests indicated that sample plot size 0.1ha of the *Acacia nilotica* inventory resulted in mean values of DBH which were not significantly different from the value obtained by 100% inventory at

p=0.0001, (Table 5.1).

Table 5.1. Means of diameter at breast height of sample plot 0.1 ha of *Acacia nilotica* as compared with that of total enumereation

Sample plot shape	Number of sample plots	Means of dbh (cm)	Duncan grouping
ular	55	37.88	
are	55	37.58	
tangular	55	37.41	
		P= 0.0001 ***=5.75***	

Means with the same letter in the same column are not significantly different.

The results also indicated that the means of basal area were not significantly different from that obtained by the 100% inventory at p=0.0001, (Table 5-2).

Table, 5.2. Means of basal area of sample plot size 0.1 ha of *Acacia nilotica*

Sample plot Shape	Number of sample plots	Mean basal area (sq.m)	Duncan Grouping
ular	55	12.0	
are	55	11.6	
Rectangular	55	11.2	
		).0001 ***=10.86***	

Means with the same letter in the same column are not significantly different.

However, the means of the number of trees obtained by the 0.1 hectare circular and 0.1 hectare square were not significantly different but that obtained by the rectangular sample plot of the rectangular sample plot was significantly different from the mean obtained using circular and square sample plots at p=0.0001, (Table 5-3).

Table, 5.3. Mean number of trees per hectare for sample plot size 0.1 ha for *Acacia nilotica*

Sample plot Shape	Number of sample plots	Number of trees /ha	Duncan grouping
ular	55	104	
are	55	99.4	A
Rectangular	55	88	
		.0001 ***=16.8***	

Means with the same letter in the same column are not significantly different.

The differences become more pronounced in the case of heights and volume estimation. The mean height obtained by the 0.1hactare circular sample plot was not significantly different from that obtained by the100% enumeration but those means obtained by the square and rectangular plots were significantly different as shown by Duncan multiple range test at p=0.0001(Table 5.4).

Table 5.4. Means of height obtained by sample plot size 0.1 ha for

Acacia nilotica

Sample plot shape	Number of sample plots	Mean height (meter)	Duncan grouping
ular	55	22.31	
Square	55	20.37	
Rectangular	55	20.16	
		).0001 ***=11.02***	

Means with the same letter in the same column are not significantly different.

The differences in volume estimates follow the same trend as that of mean height estimates. Means obtained using circular sample plot were not significantly different from the mean obtained by 100% enumeration but means obtained by rectangular or square sample plots were significantly different from that obtained by 100% at p=0.0001 (Table5.5)

Table, 5.5 Means of total volume per hectare obtained by 0.1 hectare for *Acacia nilotica*

Sample plot shape	Number of sample plots	Mean volume cu.m/ ha	Duncan grouping
ular	55	144.5	
are	55	121.9	BB
Rectangular	55	112.8	B
		P= 0.0001 ***= 21.55***	

Means with the same letter in the same column are not significantly different.

The effect of increasing the sample plot size to larger than 0.1ha has its effect on the results of comparing between sample plot shape and size.

The statistical test indicated that for the circular, square and rectangular sample plots of *Acacia nilotica* size of 0.15 ha, the means of DBH were not significantly different at p=0.35, (table 5-6)

Table, 5.6Means of diameter at breast height obtained by sample plot size 0.15 ha for Acacia *nilotica*

Sample plot shape	Number of sample plots	Means of dbh (cm)	Duncan grouping
Circular	31	37.03	
Square	31	37.47	
tangular	31	36.96	
		P= 0.35 ***V = 98.96***	

Means with the same letter in the same column are not significantly different.

but means of basal area were significantly different at p=0.0001, (table 5.7)

Table, 5.7 Means of the basal area obtained by sample plot size 0.15 ha

F for *Acacia nilotica*

Sample plot shape	Number of sample plots	Means of basal area (sq.m)	Duncan grouping
ular	31	127.17	
are	31	123.21	
tangular	31	123.65	

		P=0.0001 C.V=8.22	

Means with the same letter in the same column are not significantly different.

However the means of height were not significantly different at p=0.0001 (Table5-8).

Table, 5.8 Means of the height obtained by sample plot size 0.15 ha for *Acacia nilotica*

Sample plot shape	Number of sample plots	Means height (meter)	Duncan grouping
Circular	31	20.45	
Rectangular	31	20.24	
Square	31	20.22	
		P= 0.0001 C.V = 5.8	

Means with the same letter in the same column are not significantly different.

and means of number of trees were not significantly different at p=0.0001 (Table 5-9)

Table 5.9 Means of number of trees per hectare obtained by sample plot size 0.15 ha for *Acacia nilotica*

Sample plot shape	Number of sample plots	Mean of number of trees ha	Duncan grouping
Circular	31	94.2	AA
Rectangular	31	88.2	AA
Square	31	87.9	A
		P= 0.0001 C.V = 19.78	

Means with the same letter in the same column are not significantly different.

The means of volume on the other hand were significantly different at p= 5.14. (Table 5-10).

Table 5.10 Means of total volume per hectare obtained by sample plot Size 0.15 ha for *Acacia nilotica*

Sample plot Shape	Number of sample plots	Mean volume cu m ha	Duncan grouping
ular	31	176.2	AA
Rectangular	31	136.5	BB
Square	31	129.5	B
		P= 0.0001 C.V = 19.78	

Means with the same letter in the same column are not significantly different.

For sample plot size 0.05 ha values of *means* of DBH for the three sizes are not significantly different at p=0.0001 (Table 5.11).

Table, 5.11 Means diameter at breast height (cm) obtained by sample plot Size 0.05 ha for *Acacia nilotica*

Sample plot Shape	Number of sample plots	Mean dbh(cm)	Duncan grouping
ular	33	39.15	AA
Rectangular	33	37.84	AA
Square	33	37.76	AA
		P= 0.0001 C.V= 10.24	

Means with the same letter in the same column are not significantly different.

However the mean values of the basal area were significantly different for sample shape: circular square and rectangular at p=0.0001, (Table 5-12).

Table, 5.12.Means of basal area obtained by sample plot size 0.05 ha for *Acacia nilotica*

Sample plot shape	Number of sample plots	Mean basal area (sqm)	Duncan grouping
Circular	33	13.733	AA
Square	33	12.9	AB
Rectangular	33	11.67	BB
		P=0.0001 C.V =13.79	

Means with the same letter in the same column are not significantly different.

The mean value of the basal area for circular sample plot was not significantly different from the complete enumeration. Differences in the basal area values obtained by the three samples plot shapes (Table 5.12) may be due to the differences in number of trees per hectare. Mean values of number of trees per hectare are significantly different for the three shapes of the circular, rectangular and square (Table 5.13)

The mean of number of trees obtained by the sample plots were significantly different from that obtained by complete enumeration. at p=0.0001

Table, 5.13 Means of number of trees per ha obtained by sample plot size 0.05 ha of *Acacia nilotica*

Means with the same letter in the same column are not significantly different.

Sample plot Shape	Number of sample plots	Mean number of trees per ha	Duncan grouping
Circular	33	90	A
Square	33	79	BB
Rectangular	33	79	B
		P= 0.0001	

		C.V= 25.51	

The mean values of height were not significantly different as obtained by any of the three shapes of sample plots for the 0.05 ha size (Table5.14)

Table 5.14 Means of the height obtained by sample plot size 0.05 ha for *Acacia nilotica*

Sample plot Shape	Number of sample plots	Mean height (meter)	Duncan grouping
ular	33	20.93	AA
Square	33	20.38	AA
Rectangular	33	20.20	A
		P= 0.0001 C.V= 9.57	

Means with the same letter in the same column are not significantly different.

The results show that in all cases the mean values of volume per hectare obtained by the three shapes (circular, rectangular and square) were significantly different but that obtained by 0.05 ha circular sample plot was not significantly different from the value obtained by complete enumeration at p=0.0001 (Table 5.15).

Table, 5.15. Means of total volume in cubic meter per ha for *Acacia nilotica* based on 0.05 ha sample plot size

Sample plot Shape	Number of sample plots	Mean total volume cum/ha	Duncan grouping
ular	33	168	A
Square	33	147.5	B

Rectangular	33	146.5	B
		P= 0.0001 C.V =33.49	

Means with the same letter in the same column are not significantly different.

5.3 Total number of trees

The 0.1 hectare circular sample plot systematic sampling system provided an estimate of the total number of trees for the compartment with insignificant difference from the total number of trees given by the total enumeration (Table 5.16). Considering that sampling error of 5 - 10% is accepted then a difference of 0.1% from the complete enumeration indicates a confidently acceptable error given by systematic line plot sampling of 0.1 ha. The other sample plot shapes of the rectangular and square plots of 0.1 hectare resulted in estimates of 4% and 15% sampling error respectively.

Although the rectangular 0.1 ha sample plot provides an acceptable error Of less than 5%, it is still much greater than that obtained by the 0.1 ha circular sample plot (Table 5.16). The square sample plots of 0.1ha provided an estimate of total number of trees with error percent greater than 10% which is unacceptable.

Table (5.16) Means of total number of trees per hectare for complete enumeration and three sample plot shapes 0.1 ha

Enumeration	Total number of trees	Total number of trees per ha	Difference between totals	%
Complete	5179	103.6	0.0	0.0
Circular	5210	104	31	0.6
Rectangular	4970	99.4	209	4
Square	4400	88	779	15

The 0.05 of hectare sample plot of the three sizes (circular rectangular and square) provided estimates of the total number of trees much less than that provided by the complete enumeration (Table 5.16). All of the other sampling systems of 0.05 ha and 0.15 ha for the tree shapes provided estimates of total number of trees with 13%, 31% and 31% sampling error for the circular, rectangular and square sample plots respectively. Each of these errors is far greater than the upper limit of the acceptable sampling error10% (upper limit).How ever, the 0.05 square and 0.05 rectangular sample plot sizes (Table 5.17).

Table (5.17) Means of total number of trees per hectare for complete enumeration and three sample plot shapes 0.05 ha

Enumeration	Total number	Total number of	Difference	%

	of trees	trees per ha	between totals	
Complete	5179	103.6	0.0	0.0
Circular	4500	90	679	13
Rectangular	3950	79	1589	31
Square	3950	79	1589	31

The results indicate the advantages of the 0.1 hectare circular sample plot as compared with other shapes and sample plot sizes. The 0.1 ha circular sample plot gives estimates not significantly different from complete enumeration. The 0.15 hectare sample plot size in a circular shape follows the same trend of the 0.1 hectare circular plot in providing estimates of average DBH, average basal area and average volume in cubic meter per hectare all not significantly different from estimates of those parameters provided by complete enumeration. As for the case 0.05 of the hectare circular sample plot and the other shapes (rectangular and square) the results are significantly different for almost all parameters estimated as compared with the complete enumeration results.

The 0.1 ha circular sample plot appears to be the most acceptable for sampling with respect to thinning planning. It provides estimate of total number of trees very close to the actual. Other sizes and shapes are not suitable for thinning planning as they provide estimates of total number of trees far below the actual values.

Table (5.18) Means of total number of trees per hectare for complete enumeration and three sample plot shapes 0.15 ha

Enumeration	Total number of trees	Total number of trees per ha	Differences between totals	%
Complete	5179	103.6	0.0	0.0
Circular	4410	88.2	469	10
Rectangular	4710	94.2	769	14
square	4395	87.9	784	15

5.4 Diameter distribution

Analysis of the diameter distribution of *A.nilotica* stand obtained from the 100% enumeration (Table 5.19) indicates that the falls in DBH range 12.0-79.0 cm. The result of 100% enumeration was used as true value to provide the basis for comparison between the different sampling systems by the size and shape. A prerequisite for diameter distribution is the classification of the trees into suitable classes based on a compatible class range. Various criteria of a compatible class range are used but a practical one is based on the value of the average diameter of in the class compared with the diameter value at the mid-point of the class range

The data of measured for the complete enumeration, the 0.1 ha circular, rectangular and square sample plot size were used . The data of dbh classified into class range of 2.0 cm, 3.0 cm, and 4.0 cm were tested for compatibility. The compatible diameter grouping is based on a class range the diameter at mid-point of which is equal to or close to the average diameter of the class range. For large dbh classes the average density per hectare is low so it is not expected to find a high compatibility between the average dbh per class and the class mid-point.

However the diameter grouping with 4.0 cm class range (Tables 5.19,

5.20, 5.21, 5.22) tends to group the trees within dbh classes in a better compatibility than the other grouping of 2.0cm (Appendix 5.1, 5.3, 5.5, 5.7) and 3.0cm class range (Appendix 5.2, 5.4, 5.6, 5.8) Within most of the classes for the 4.0 cm range the diameter distribution of the trees tends toward systemrical distribution, with many cases that the average dbh per class is closer to the mid –point of the class. Accordingly the 4.0 cm range diameter grouping was used for developing diameter -distribution curves for the circular, rectangular and square sample plots for the 0.1 ha in comparison with the complete enumeration. The 4.0 cm class range provides average dbh in the classes most of them are very close in value to that at the mid-point (Table 5.19, 5.20, 2.21, 5.22).

Table (5.19) Diameter distribution by dbh classes for complete enumeration using 4.0 class range

Range (4cm)	Number of trees	Average dbh cm	mid-point dbh cm
12-15.9	47	14.0	13.9
16-19.9	256	18.0	17.9
20-23.9	615	22.0	21.9
24-27.9	682	26.0	25.9
28-31.9	769	40.0	29.9
32-35.9	597	34.0	33.9

36-39.9	532	38.0	37.9
40-43.9	449	42.0	41.9
44-47.9	364	46.0	45.9
48-51.9	389	60.0	49.9
52-55.9	237	54.0	53.9
56-59.9	61	58.0	57.9
60-63.9	81	62.0	61.9
64-67.9	61	66.0	65.9
68-71.9	26	70.0	69.9
72-75.9	10	74.0	73.9
76-79.9	3	78.0	77.9

Table (5.20) Diameter distribution by dbh classes for circular sample plot 0.1ha.

using 4.0 cm class

Range (4cm)	Number of trees	verage dbh 22.0cm	Mid-point dbh
12-15.9	81	14.5	13.9
16-19.9	230	17.8	17.9
20-23.9	481	21.5	21.9
24-27.9	461	25.8	25.9
28-31.9	741	29.3	29.9
32-35.9	670	33.3	33.9

36-39.9	610	37.6	37.9
40-43.9	610	41.3	41.9
44-47.9	461	45.2	45.9
48-51.9	470	49.5	49.9
52-55.9	141	53.4	53.9
56-59.9	21	56.0	57.9
60-63.9	70	60.6	62.9
64-67.9	101	65.3	66.9
68-71.9	61	70.0	69.9
72-75.9	11	75.0	73.9

Table (5.21) Diameter distribution by dbh classes for square sample plot0.1ha.

using 4.0 cm class Range

Range (4.0cm)	Number of trees	Average dbh	Mid-point dbh
12-15.9	81	14.1	13.9
16-19.9	130	17.0	17.9
20-23.9	461	21.4	21.9
24-27.9	350	25.7	25.9
28-31.9	790	29.2	29.9
32-35.9	569	33.4	33.9

36-39.9	509	37.6	37.9
40-43.9	489	41.5	41.9
44-47.9	300	45.2	45.9
48-51.9	429	49.6	49.9
52-55.9	61	53.3	53.9
56-59.9	10	56.0	57.9
60-63.9	90	60.8	61.9
64-67.9	81	65.3	65.9
68-71.9	41	70.0	69.9
72-75.9	9	75.0	73.9

Table (5.22) Diameter distribution by dbh classes for rectangular sample plot 0.1ha. using 4.0 cm class Range

Range (4cm)	Number of trees	Average dbh	Mid-point dbh
12-15.9	110	14.1	13.9
16-19.9	201	17.8	17.9
20-23.9	501	21.7	21.9
24-27.9	461	25.6	25.9
28-31.9	890	29.3	29.9
32-35.9	610	33.3	33.9

36-39.9	621	37.5	37.9
40-43.9	429	41.5	41.9
44-47.9	360	45.4	45.9
48-51.9	460	49.5	49.9
52-55.9	109	53.5	53.9
56-59.9	9	56.0	57.9
60-63.9	100	60.3	61.9
64-67.9	69	65.3	65.9
68-71.9	40	70.0	69.9

When comparing between diameter distribution within each sample system e.g. circular shape 0.1 ha the 4-cm class range gives better results than the 2-cm and the 3-cm class range .The number of classes in the 4-cm class range, with average dbh value closer to the mid –point value, is greater than in the case of the 2-cm and the 3-cm class range (Table5.19 and appendix 5.3-5.4). This applies to the case of complete enumeration, (Table5.19 and appendix 5.1and 5.2 the rectangular (Table 5.21 and appendix 5.5-5.6) and square shapes (Table 5.21 and appendix 5.7-5.8).More improvement may be attained with in creasing class range.

Fig. (5.1): Diameter distribution of complete enumeration and circular, square, rectangular sample plot size 0.1ha using 4.0 cm class range

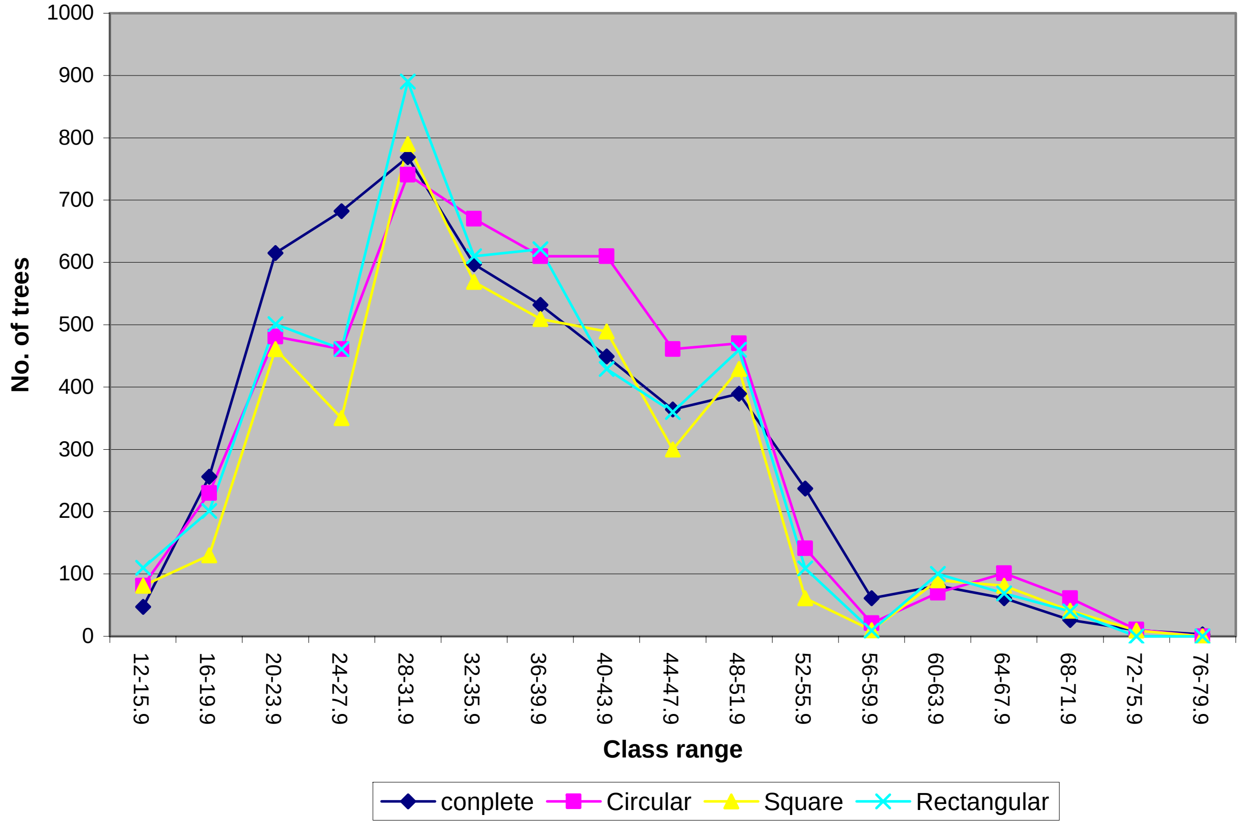


Fig. (5.2): Diameter distribution of complete enumeration and circular, square, rectangular sample plot size 0.1ha using 2.0cm class range

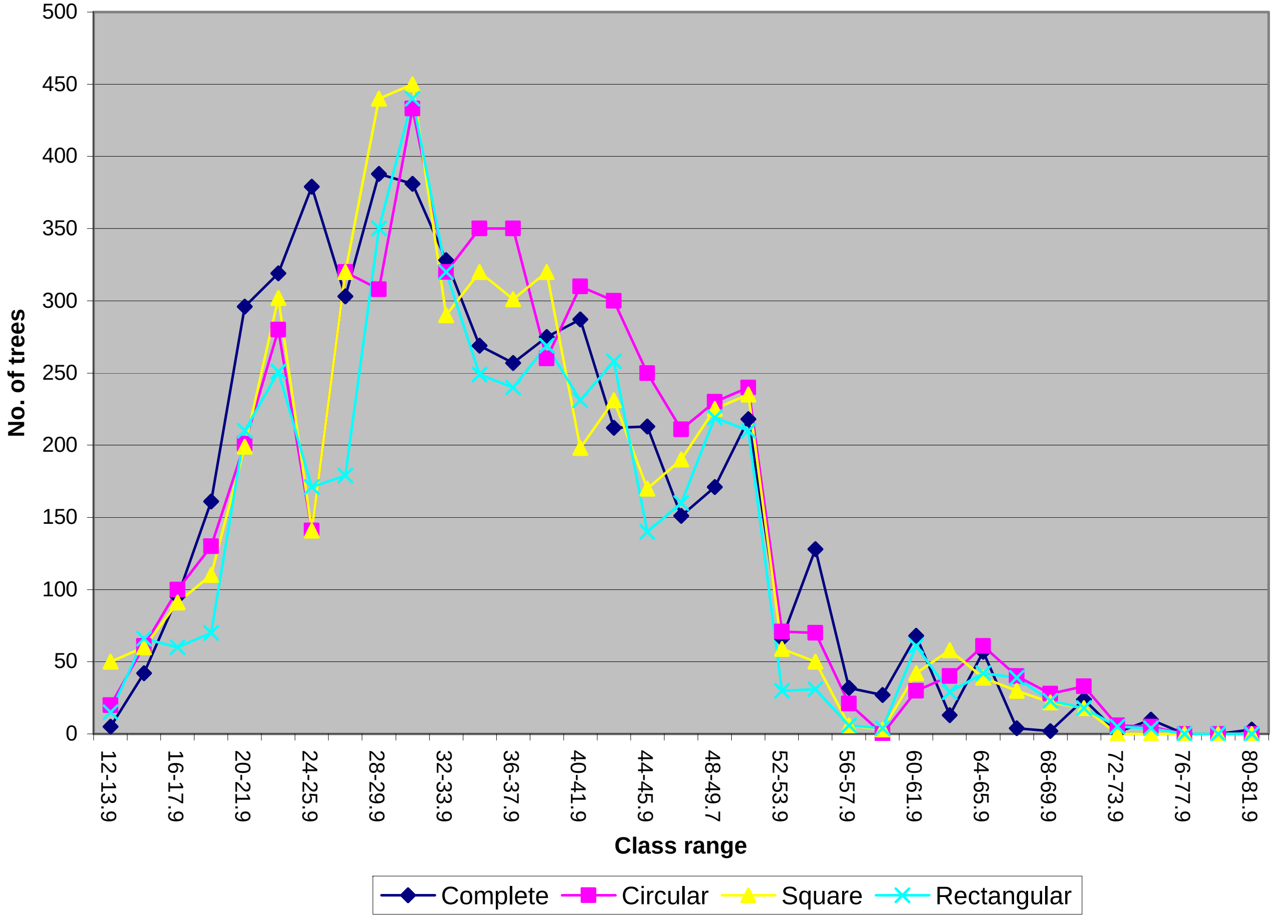


Fig. (5.3): Diameter distribution of complete enumeration and circular, square and rectangular sample plot size 0.1ha using 3.0cm class range

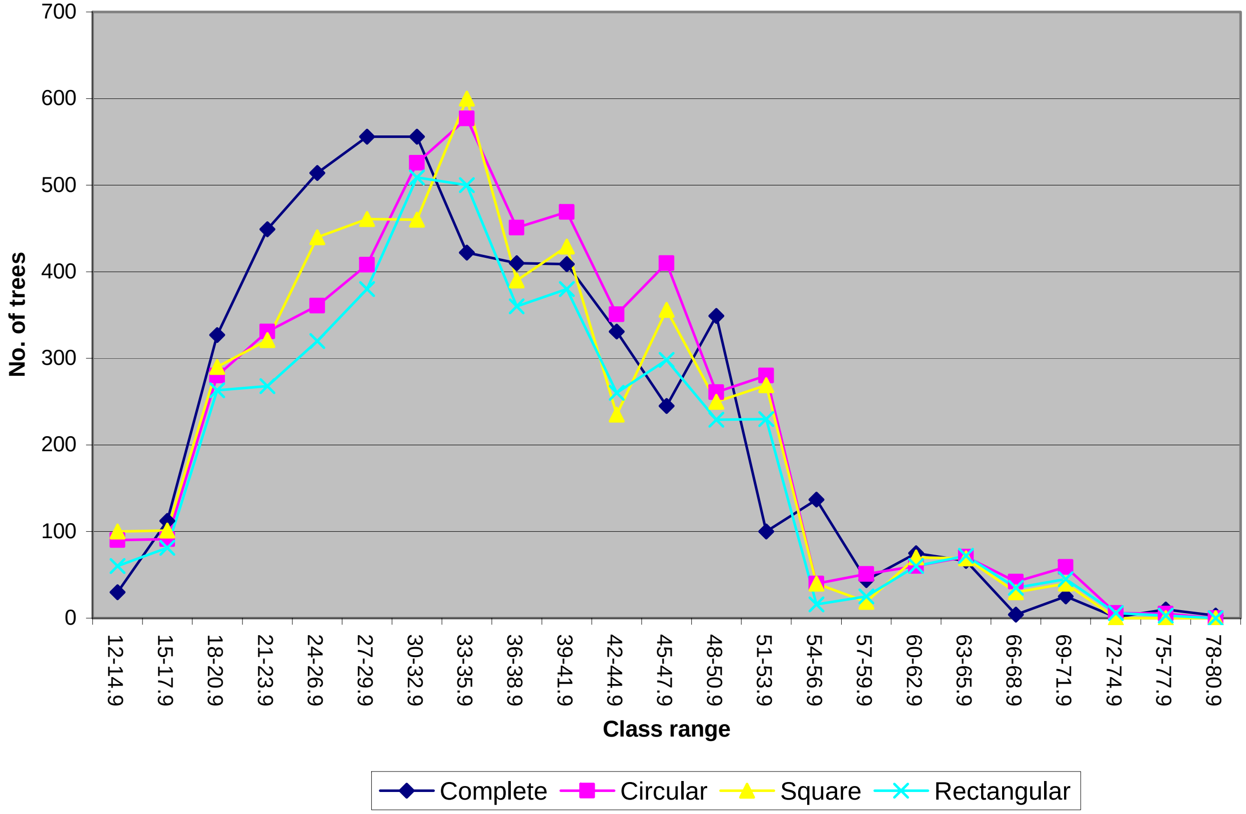


Fig (5.4): Diameter distribution of complete enumeration and circular, sqaure, rectangular sample plot size 0.05 ha using 4.0cm class range

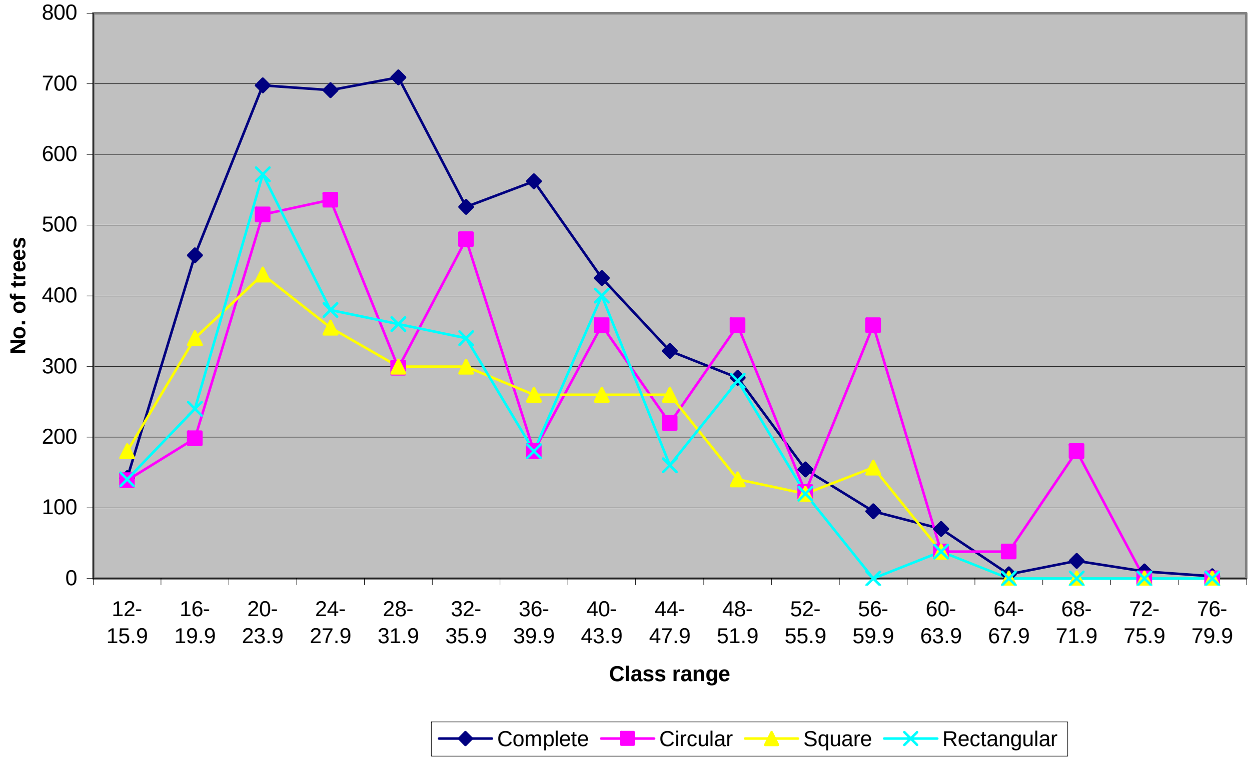
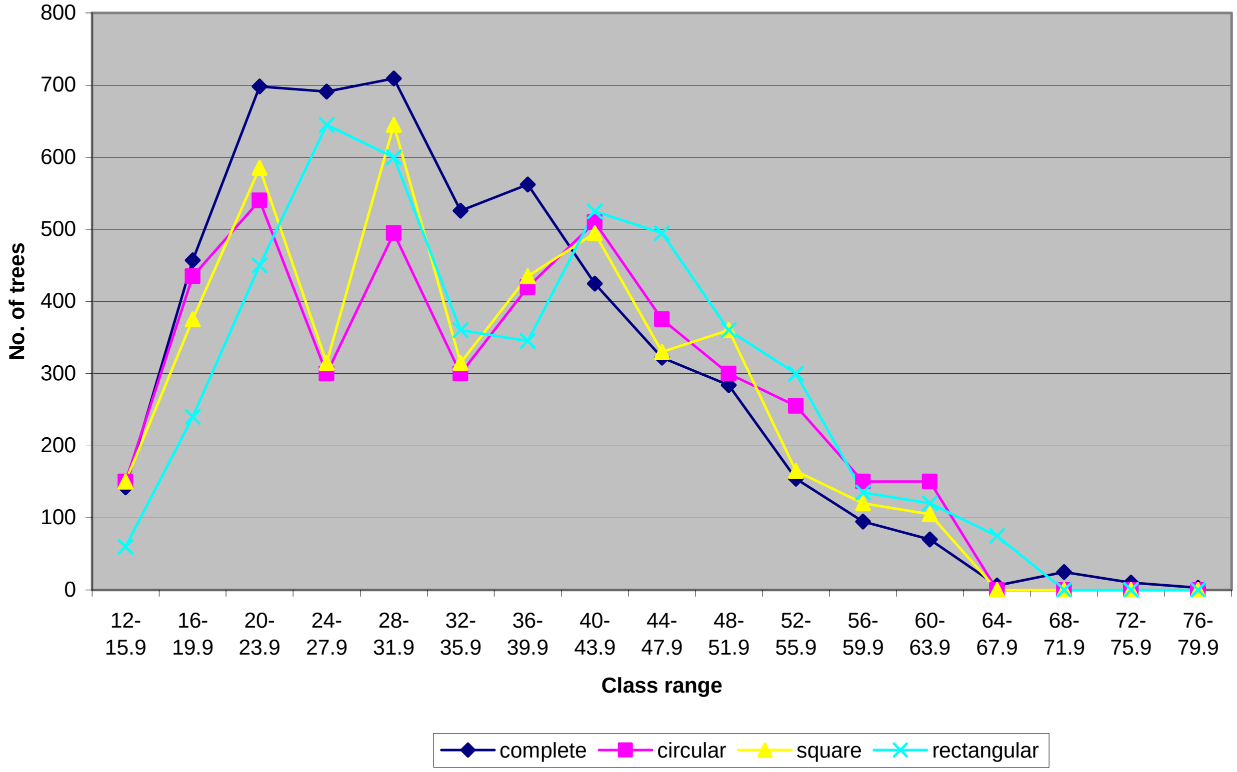


Fig (5.5); Diameter distribution of complete enumeration and circular, square, rectangular sample size 0.15 ha using 4.0 cm class range



Chapter 6

Conclusions and Recommendation

Conclusions

1. Sunt plantations in the Blue Nile are managed to satisfy different needs on sustainable management. This is justification for study the effects of size and shape of sample plot accuracy in estimates of number of trees and volume estimate.

2. Circular sample plots are appropriate sample plot in sunt plantations in the Blue Nile with different sizes this agreement to experimental of American and Sudian.

3. The 0.1 ha circular sample plot systematic sampling provided an estimate of the total number for the compartment with insignificance differences from the total number of trees giving by the total complete enumeration.

4. The 4.0 cm classes range tended to the group of trees dbh classes in a better compatibility than the other grouping (2.0 cm, 3.0 classes range). 5.Circular sample plot it is too easy but square and rectangular sample plot it is too difficult to establishment and it is impractical.

Recommendations

1. Circular sample plot it is re commended to use or apply for the inventory of Sunt plantations in the Blue Nile and the establishment it is too easy and practice.

2. The 0.1 ha circular sample plot is a suitable for sampling concerned with thinning planning.

3. Compartment 3,4and 5 are recommended to be a permanent sample plots with the present database as a foundation for the future activities.

Further research:

1. To investigate different sizes and shapes of sample plots with different ages in Sunt plantations.

2. To investigate the time factor and cost in relation to the different sample size and shape procedures

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Appendix (5.1) Diameter distribution by dbh classes for complete enumeration using 2.0 cm class range

Range (2cm)	Number of trees	Average dbh c.m	Mid-point dbh c.m
12-13.9	5	12.0	12.9
14-15.9	42	14.4	14.9
16-17.9	95	16.6	16.9
18-19.9	161	18.6	18.9
20-21.9	296	20.5	20.9
22-23.9	319	22.5	22.9
24-25.9	379	24.5	24.9
26-27.9	303	26.6	26.9
28-29.9	388	28.5	28.9
30-31.9	381	30.5	30.9
32-33.9	328	32.4	32.9
34-35.9	269	34.4	34.9
36-37.9	257	36.5	36.9
38-39.9	275	38.5	38.9
40-41.9	287	40.5	40.9
42-43.9	212	42.5	42.9
44-45.9	213	44.5	44.9
46-47.9	151	46.7	46.9
48-49.7	171	48.6	48.9
50-51.9	218	50.2	50.9
52-53.9	66	52.6	52.9
54-55.9	128	54.8	54.9
56-57.9	32	56.5	65.9
58-59.9	27	58.4	58.9
60-61.9	68	60.3	60.9
62-63.9	13	62.5	62.9
64-65.9	57	64.8	64.9
66-67.9	4	66.6	66.9
68-69.9	2	68.5	68.9
70-71.9	24	70.0	70.9
72-73.9	1	72.0	72.9
74-75.9	10	75.0	74.9

76-77.9	0	0	76.9
78-79.9	0	0	79.9
80-81.9	3	80	80.9

Appendix (5.2) Diameter distribution by dbh classes for complete enumeration using 3.0 cm class range

Range (3cm)	Number of trees	Average dbh cm	Mid–point dbh cm
12-14.9	30	14.4	143.5
15-17.9	112	17.1	16.5
18-20.9	327	20.1	19.5
21-23.9	449	23.1	22.5
24-26.9	514	26	25.5
27-29.9	556	29.3	28.5
30-32.9	556	32	31.5
33-35.9	422	35	34.5
36-38.9	410	38	37.5
39-41.9	409	41	40.5
42-44.9	331	44.1	43.5
45-47.9	245	47.1	46.5
48-50.9	349	49.8	49.5
51-53.9	100	53.1	52.5
54-56.9	137	55.5	55.5
57-59.9	44	59.5	58.5
60-62.9	75	61.7	61.5
63-65.9	66	64.9	64.5
66-68.9	4	67.8	67.5
69-71.9	25	70.1	70.5
72-74.9	1	75	73.5
75-77.9	10	0	76.5
78-80.9	3	80	79.5

Appendix (5.3) Diameter distribution by dbh classes for circular sample plot 0.1ha using 2.0 cm class range

Range (2cm)	Number of trees	Average dbh	Mid-point dbh
12-13.9	20	12.0	12.9
14-15.9	61	14.7	14.9
16-17.9	100	16.4	16.9
18-19.9	130	18.5	18.9
20-21.9	201	20.5	20.9
22-23.9	280	22.5	22.9
24-25.9	141	24.6	24.9
26-27.9	320	26.6	26.9
28-29.9	308	28.4	28.9
30-31	433	30.6	30.9
32-33.9	320	32.3	32.9
34-35.9	350	34.5	34.9
36-37.9	350	36.7	36.9
38-39.9	260	38.5	38.9
40-41.9	310	40.4	40.9
42-43.9	300	42.4	42.9
44-45.9	250	44.4	44.9
46-47.9	211	46.7	46.9
48-49.9	230	48.4	48.9
50-51.9	240	50.4	50.9
52-53.9	71	52.1	52.9
54-55.9	70	54.6	54.9
56-57.9	21	56.0	56.9
58-59.9	0	0.0	0
60-61.9	30	63.3	60.9
62-63.9	40	62.0	62.9
64-65.9	61	65.0	64.9
66-67.9	40	66.0	66.9
68-69.9	28	0.0	68.9
70-71.9	33	70.0	70.9
72-73.9	6	0.0	72.9
74-75.9	5	75.0	74.9

Appendix (5.4) Diameter distribution by dbh classes for circular sample plot 0.1ha using 3.0 cm class range

Range (3cm)	Number of trees	Average dbh	Mid–point dbh
12-14.9	90	13.3	13.5
15-17.9	91	16.1	16.5
18-20.9	280	19.2	19.5
21-23.9	331	22	22.5
24-26.9	361	25.2	25.5
27-29.9	408	28.1	28.5
30-32.9	526	31.3	31.5
33-35.9	577	34.1	34.5
36-38.9	451	37.1	37.5
39-41.9	469	39.9	40.5
42-44.9	351	43.1	43.5
45-47.9	410	46.1	46.5
48-50.9	261	49.1	49.5
51-53.9	280	51.5	52.5
54-56.9	40	54.9	55.5
57-59.9	51	0.0	0.0
60-62.9	60	60.6	61.5
63-65.9	71	65.0	64.5
66-68.9	42	66.0	67.5
69-71.9	59	70.0	70.5
72-74.9	6	0.0	73.5
75-77.9	5	75.0	76.5

Appendix (5.5) Diameter distribution by dbh classes for rectangular sample plot 0.1ha. Using 2.0 cm class Range

Range (2cm)	Number of trees	Average bh	Mid-point dbh
12-13.9	50	12.0	12.9
14-15.9	60	14.6	14.9
16-17.9	91	16.5	16.9
18-19.9	110	18.4	18.9
20-21.9	199	20.5	20.9
22-23.9	302	22.5	22.9
24-25.9	141	24.6	24.9
26-27.9	320	26.7	26.9
28-29.9	440	28.4	28.9
30-31.9	450	30.5	30.9
32-33.9	290	32.3	32.9
34-35.9	320	34.5	34.9
36-37.9	301	36.4	36.9
38-39.9	320	38.5	38.9
40-41.9	198	40.3	40.9
42-43.9	231	42.7	42.9
44-45.9	170	44.5	44.9
46-47.9	190	46.6	46.9
48-49.9	225	48.5	48.9
50-51.9	235	50.3	50.9
52-53.9	59	52.2	52.9
54-55.9	50	54.7	54.9
56-57.9	6	56.0	56.9
58-59.9	3	0.0	58.9
60-61.9	42	60.1	60.9
62-63.9	58	62.0	62.9
64-65.9	39	65.3	64.9
66-67.9	30	66.0	66.9
68-69.9	22	0.0	68.9
70-71.9	18	70.0	70.9

Appendix (5.6) Diameter distribution by dbh classes for rectangular sample plot

0.1ha using 3.0 cm class range

Range (3cm)	Number of trees	Average	Mid -point
12-14.9	100	13.5	13.5
15-17.9	101	16.0	16.5
18-20.9	290	19.2	19.5
21-23.9	321	22.2	22.5
24-26.9	440	24.9	25.5
27-29.9	461	28.1	28.5
30-32.9	460	31.1	31.5
33-35.9	600	34.1	34.5
36-38.9	390	37.0	37.5
39-41.9	429	39.8	40.5
42-44.9	235	43.3	43.5
45-47.9	356	46.1	46.5
48-50.9	250	49.2	49.5
51-53.9	269	51.5	52.5
54-56.9	40	54.8	55.5
57-59.9	19	0.0	0
60-62.9	70	63.3	61.5
63-65.9	69	65.0	64.5
66-68.9	30	66.0	67.5
69-71.9	40	70.0	70.5

Appendix (5.7) Diameter distribution by dbh classes for square sample plot 0.1ha using 2.0 cm class range

Range (2.0cm)	Number of trees	Average dbh	Mid-point dbh
12-13.9	15	12.0	12.9
14-15.9	66	14.4	14.9
16-17.9	60	16.4	16.9
18-19.9	70	18.5	18.9
20-21.9	210	20.5	20.9
22-23.9	251	22.6	22.9
24-25.9	171	24.6	24.9
26-27.9	179	26.6	26.9
28-29.9	350	28.4	28.9
30-31.9	440	30.6	30.9
32-33.9	320	32.3	32.9
34-35.9	249	34.6	34.9
36-37.9	240	36.5	36.9
38-39.9	269	38.6	38.9
40-41.9	231	40.4	40.9
42-43.9	258	42.6	42.9
44-45.9	140	44.5	44.9
46-47.9	160	46.6	46.9
48-49.9	219	49.5	48.9
50-51.9	210	50.3	50.9
52-53.9	30	52.3	52.9
54-55.9	31	54.3	54.9
56-57.9	6	56.0	56.9
58-59.9	4	0.0	0
60-61.9	61	60.3	60.9
62-63.9	29	62.5	62.9
64-65.9	42	65.0	64.9
66-67.9	39	66.0	66.9
68-69.9	23	0.0	68.9
70-71.9	18	70.0	70.9
72-73.9	5	0.0	72.9
74-75.9	4	75.0	74.9

Appendix (5.8) Diameter distribution by dbh classes for square sample plot size 0.1ha using 3.0 cm class range

Range (3cm)	Number of trees	Average dbh	Mid –point dbh
12-14.9	60	13.8	13.5
15-17.9	81	15.0	16.5
18-20.9	263	19.5	19.5
21-23.9	268	20.0	22.5
24-26.9	320	25.3	25.5
27-29.9	380	28.2	28.5
30-32.9	509	31.2	31.5
33-35.9	500	34.1	34.5
36-38.9	360	37.0	37.5
39-41.9	380	39.9	40.5
42-44.9	260	43.1	43.5
45-47.9	298	46.0	46.5
48-50.9	229	49.3	49.5
51-53.9	230	51.4	52.5
54-56.9	16	54.8	55.5
57-59.9	25	0.0	58.5
60-62.9	60	60.5	61.5
63-65.9	72	64.7	64.5
66-68.9	35	66.0	67.5
69-71.9	45	70.0	70.5
72-74.9	6	0.0	73.5
75-77.9	3	75.0	76.5

Appendix (5.9) Diameter distribution by dbh classes for circular sample

Plot size 0.15 ha. using 4.0 cm class Range

Range (4cm)	Number of trees	Average dbh	Mid-point dbh
12-15.9	150	14.1	13.9
16-19.9	435	17.8	17.9
20-23.9	540	21.7	21.9
24-27.9	300	25.6	25.9
28-31.9	495	29.3	29.9
32-35.9	300	33.3	33.9
36-39.9	420	37.5	37.9
40-43.9	510	41.5	41.9
44-47.9	375	45.4	45.9
48-51.9	300	49.5	49.9
52-55.9	255	53.5	53.9
56-59.9	150	56.0	57.9
60-63.9	150	60.3	61.9

Appendix (5.10) Diameter distribution by dbh classes for square sample

plot size 0.15h a. using 4.0 cm class Range

Range (4cm)	Number of trees	Average dbh	Mid-point dbh
12-15.9	150	14.1	13.9
16-19.9	375	17.8	17.9
20-23.9	585	21.7	21.9
24-27.9	315	25.6	25.9
28-31.9	645	29.3	29.9
32-35.9	315	33.3	33.9
36-39.9	435	37.5	37.9
40-43.9	495	41.5	41.9
44-47.9	330	45.4	45.9
48-51.9	360	49.5	49.9
52-55.9	165	53.5	53.9
56-59.9	120	56.0	57.9
60-63.9	105	60.3	61.9

Appendix (5.11) Diameter distribution by dbh classes for rectangular sample

Plot size 0.1ha. using 4.0 cm class Range

Range (4cm)	Number of trees	Average dbh	Mid- point dbh
12-15.9	60	14.1	13.9
16-19.9	240	17.8	17.9
20-23.9	450	21.7	21.9
24-27.9	645	25.6	25.9
28-31.9	600	29.3	29.9
32-35.9	360	33.3	33.9
36-39.9	345	37.5	37.9
40-43.9	525	41.5	41.9
44-47.9	495	45.4	45.9
48-51.9	360	49.5	49.9
52-55.9	300	53.5	53.9
56-59.9	135	56.0	57.9
60-63.9	120	60.3	61.9
64-67.9	75	65.3	65.9

Appendix (5.12) Diameter distribution by dbh classes for circular sample plot size 0.05 ha using 4.0 class range

Range (4cm)	Number of trees	Average dbh cm	Mid-point dbh cm
12-15.9	139	14.0	13.9
16-19.9	198	18.0	17.9
20-23.9	515	22.0	21.9
24-27.9	536	26.0	25.9
28-31.9	298	40.0	29.9
32-35.9	480	34.0	33.9
36-39.9	180	38.0	37.9
40-43.9	358	42.0	41.9
44-47.9	220	46.0	45.9
48-51.9	358	60.0	49.9
52-55.9	122	54.0	53.9
56-59.9	358	58.0	57.9
60-63.9	38	62.0	61.9
64-67.9	38	66.0	65.9
68-71.9	180	70.0	69.9

Appendix (5.13) Diameter distribution by dbh classes for square sample plot size

0.05 ha using 4.0 class range

Range (4cm)	Number of trees	Average dbh cm	Mid-point dbh cm
12-15.9	180	14.0	13.9
16-19.9	340	18.0	17.9
20-23.9	430	22.0	21.9
24-27.9	355	26.0	25.9
28-31.9	300	40.0	29.9
32-35.9	300	34.0	33.9
36-39.9	260	38.0	37.9
40-43.9	260	42.0	41.9
44-47.9	260	46.0	45.9
48-51.9	140	60.0	49.9
52-55.9	120	54.0	53.9
56-59.9	157	58.0	57.9
60-63.9	38	62.0	61.9

Appendix (5.14) Diameter distribution by dbh classes for rectangular samp le plot size 0.05 ha using 4.0 class range

Range (4cm)	Number of trees	Average dbh cm	Mid-point dbh cm
12-15.9	140	14.0	13.9
16-19.9	240	18.0	17.9
20-23.9	572	22.0	21.9
24-27.9	380	26.0	25.9
28-31.9	360	40.0	29.9
32-35.9	340	34.0	33.9
36-39.9	180	38.0	37.9
40-43.9	400	42.0	41.9
44-47.9	160	46.0	45.9
48-51.9	280	60.0	49.9
52-55.9	120	54.0	53.9
56-59.9	00	58.0	57.9
60-63.9	38	62.0	61.9